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FINAL REPORT

Measurement of long-term surface inflation signals at GLISP with two independent tiltmeter systems

(AOSTRA Agreement No. 263C)

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NOTE CONCERNING THIS REPORT

Please note that there was an extension of the term of this agreement from July 1, 1987 to December 31, 1987 that overlapped with new Agreement 263H - Measurement and analysis of long-term tilt from the tiltmeter boreholes at the AOSTRA/AMOCO GLISP Pilot Project.

For this reason, and since Agreement 263H was a continuation of the project, the first Progress Report of Agreement 263H should also be considered the Final Report for Project 263C.

Therefore, for the details of the Final Report for Agreement 263C, please see the report for Agreement 263H submitted December 31, 1987.

However, to satisfy the requirement that a separate Final Report for Agreement 263C be submitted, the work of that agreement is summarized here.

Introduction

The objective of this agreement was to undertake a field comparison between the University of Alberta biaxial mercury-level borehole tiltmeters and Hunter Geophysics biaxial bubble sensor tiltmeters. The extension (that overlapped with Agreement 263H) was to assist in the funding with Agreement 263H and therefore to begin work to measure the long-term tilt at the GLISP site.

Comparison of the two types of tiltmeters

Insufficient funds were available to do the comparison between two each of the two types of instruments properly installed in four separate boreholes. Therefore, the bubble sensors were mounted on top of the U of A sensors (please see June 1987 report for details). For this reason, borehole instability does not enter the comparison. Therefore, no conclusions could be drawn concerning the manner in which the U of A tiltmeters were installed in cased boreholes compared with the sand-pack installation normally employed for the Hunter Geophysics instruments.

One pair of the two types of tiltmeters was operated simultaneously from March 27, 1987 to June 21, 1987. Because of a broken levelling shaft and other delays, the second pair was operated from April 27 to June 21, 1987. Examples of the records are given in the report of June 27, Figs. 24 and 25. Generally it was found that, in this type of application and mounting mode, the two types of tiltmeters reported similar tilt responses. Figs. 24a and b, from the report of June, 1987 and reproduced here as Figs. 1 and 2 show the comparison for the North tiltmeter for a 51 day recording period and Figs. 25a, b of the previous report show the comparison for the South tiltmeters for the 76 days that they were operated (Figs. 3 and 4 here).

It was found that the long-term drift between the two instruments seldom exceeded 20 μ radians over the three month period. The levelling screws on the mounting pod could have been a source for this, and the recommendation is to undertake further relative stability testing, with a better coupling arrangement and at a quiet site.

The method of installation is still a source of uncertainty. Even in the cased boreholes used at GLISP, it has subsequently been found that coupling exists between the well and the pad, particularly in winter (please see the Progress Report of June 30, 1988 for Agreement No. 263H). This poses serious questions concerning the usual method of installation of the bubble level sensors if they are to be used for monitoring long-term tilt.

Long-term monitoring at GLISP

The objective of the long-term monitoring at the AOSTRA/AMOCO GLISP Pilot is to trace the Earth surface tilt response to the steam injection and related water movement through the formations at the site and to attempt to relate the tilt to the various enhancement process activities in order to better understand the long-term recovery process.

The report for Agreement 263H of December 21, 1987 shows that the tilt response from day-to-day can be correlated with process activity. An example is given in Fig. 9c of that report and is reproduced here as Fig. 5. Subsequent work has shown relationships between tilt and individual events.

In addition, there is a long-term effect, and this is illustrated by the tilt migration plot of Fig. 6 of the report of June 30, 1988 and given here as Fig. 6.

Figure 1

North well (South tilt): Tilt records of the University of Alberta and Hunter bubble sensor tiltmeter and the difference trace.

GLISP: NORTH TILTMETER
WOODS VS. U OF A

APRIL 28 - JUNE 16
(1500) (2024)

SOUTH TRACE

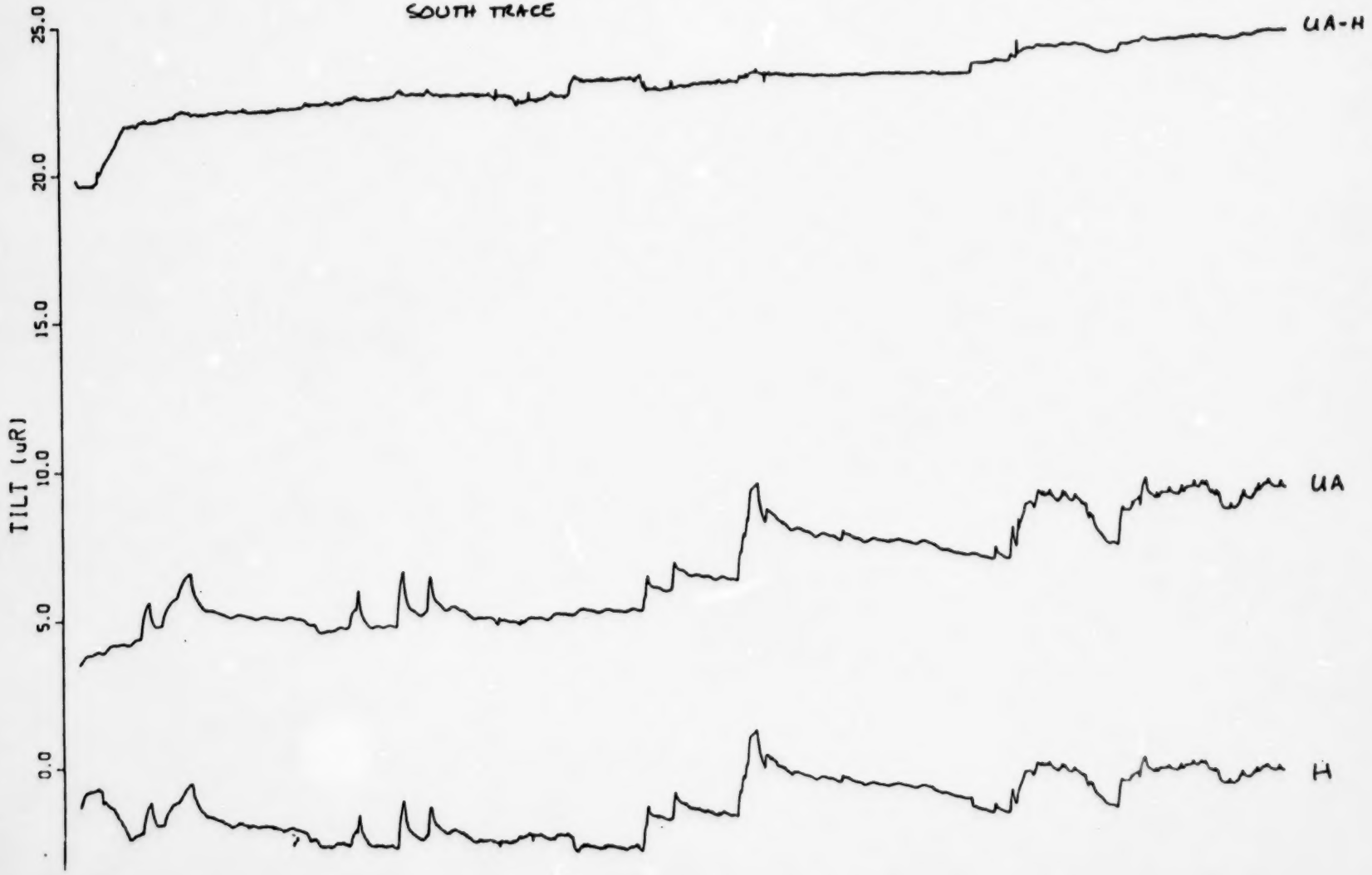

Figure 2

North well (West tilt): Tilt records of the University of Alberta and Hunter bubble sensor tiltmeters and the difference trace.

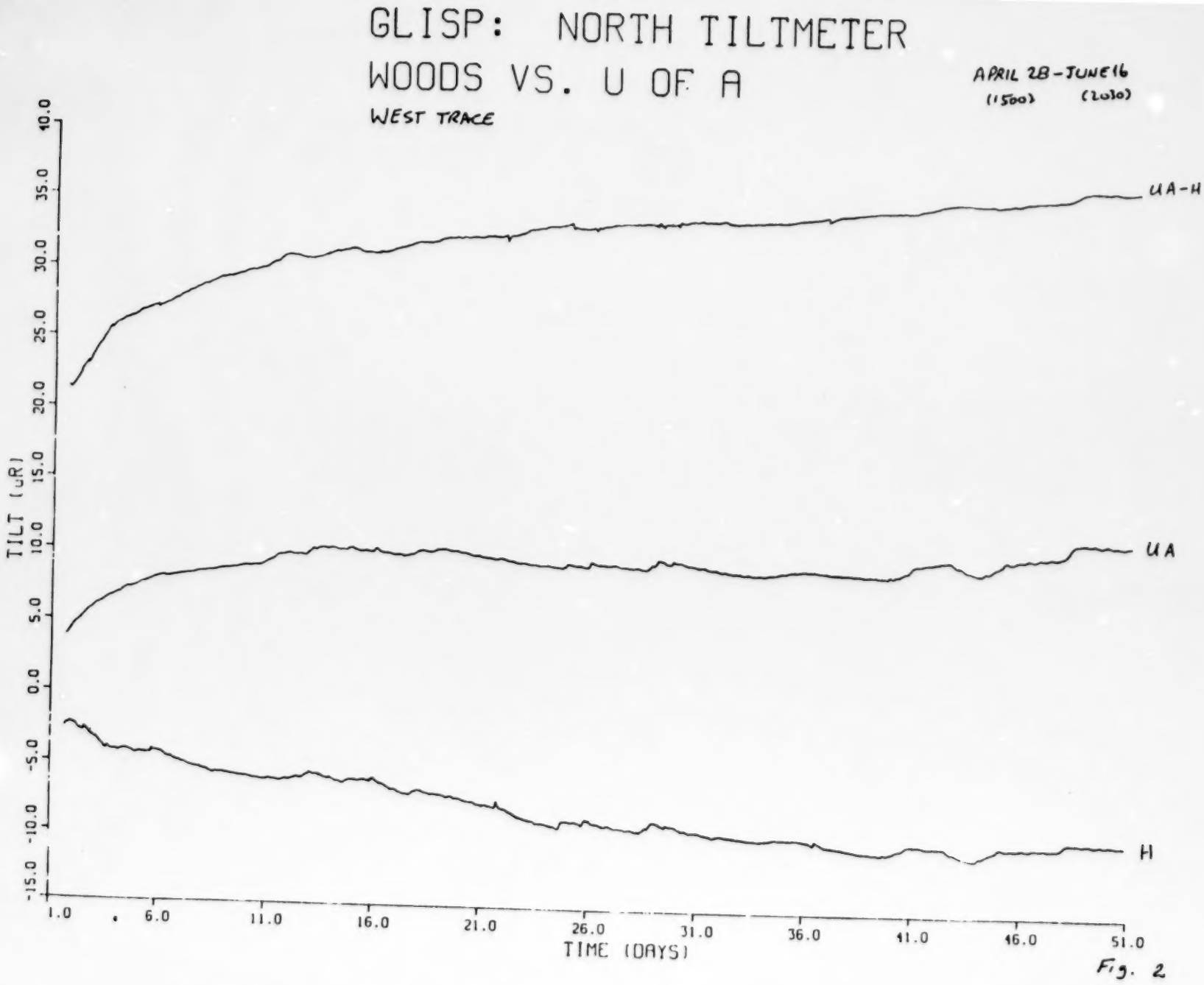
GLISP: NORTH TILTMETER
WOODS VS. U OF A
WEST TRACE
APRIL 28-JUNE 16
(1500) (2030)
UA-H
UA
H
TILT (uR)
10.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
1.0
6.0
11.0
16.0
21.0
26.0
31.0
36.0
41.0
46.0
51.0
TIME (DAYS)

Fig. 2

Figure 3

South well (South tilt): Tilt records of the University of Alberta and Hunter bubble sensor tiltmeter, and the difference trace.

GLISP: SOUTH TILTMETER
WOODS VS. U OF A

SOUTH TRACE

APRIL 2 - JUNE 16
(2100) (2620)

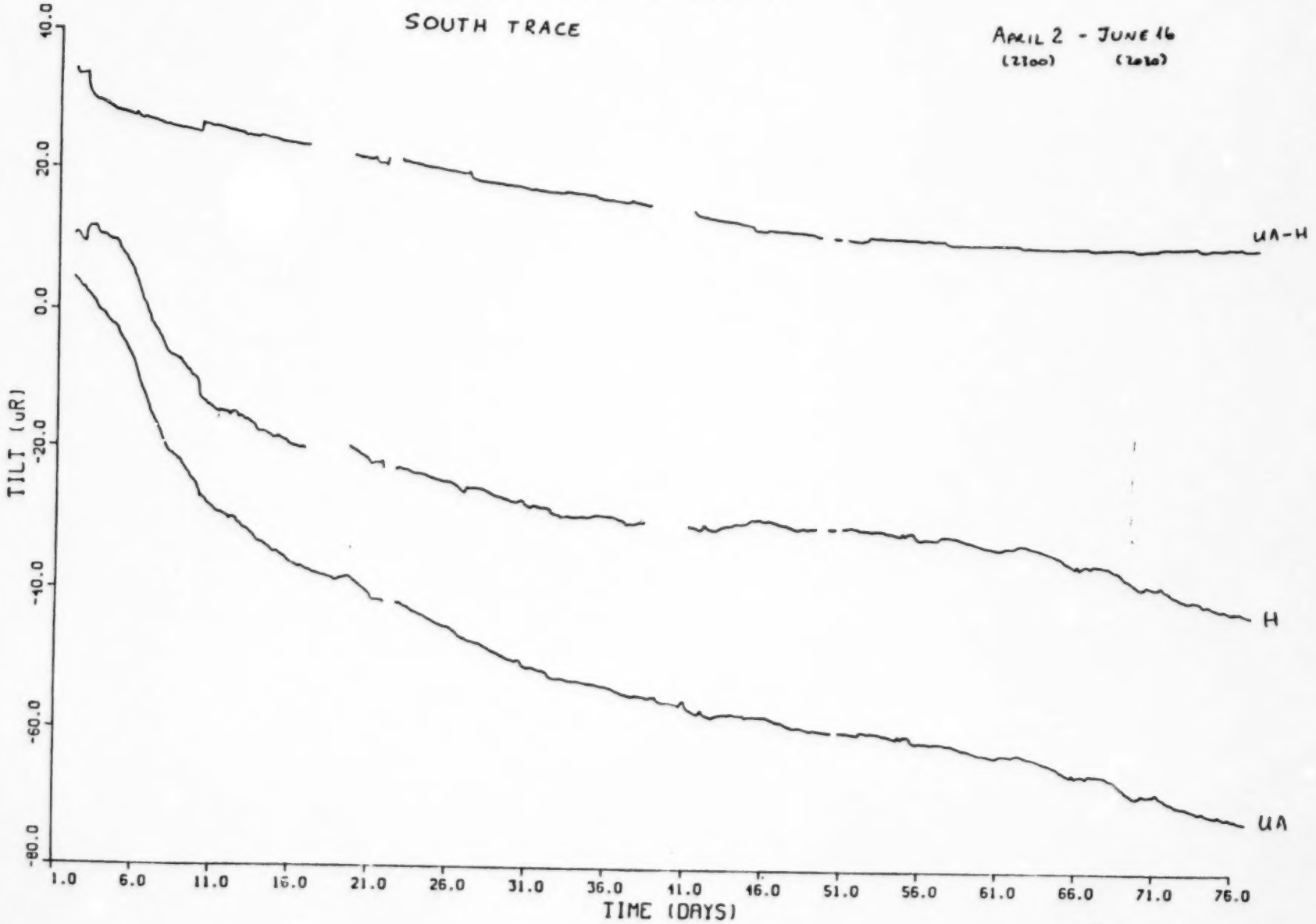

Fig. 3

Figure 4

South well (West tilt): Tilt records of the University of Alberta and Hunter bubble sensor tiltmeter and the difference trace.

GLISP: SOUTH TILTMETER
WOODS VS. U OF A

WEST TRACE

APRIL 2 - JUNE 16
(2300) (2016)

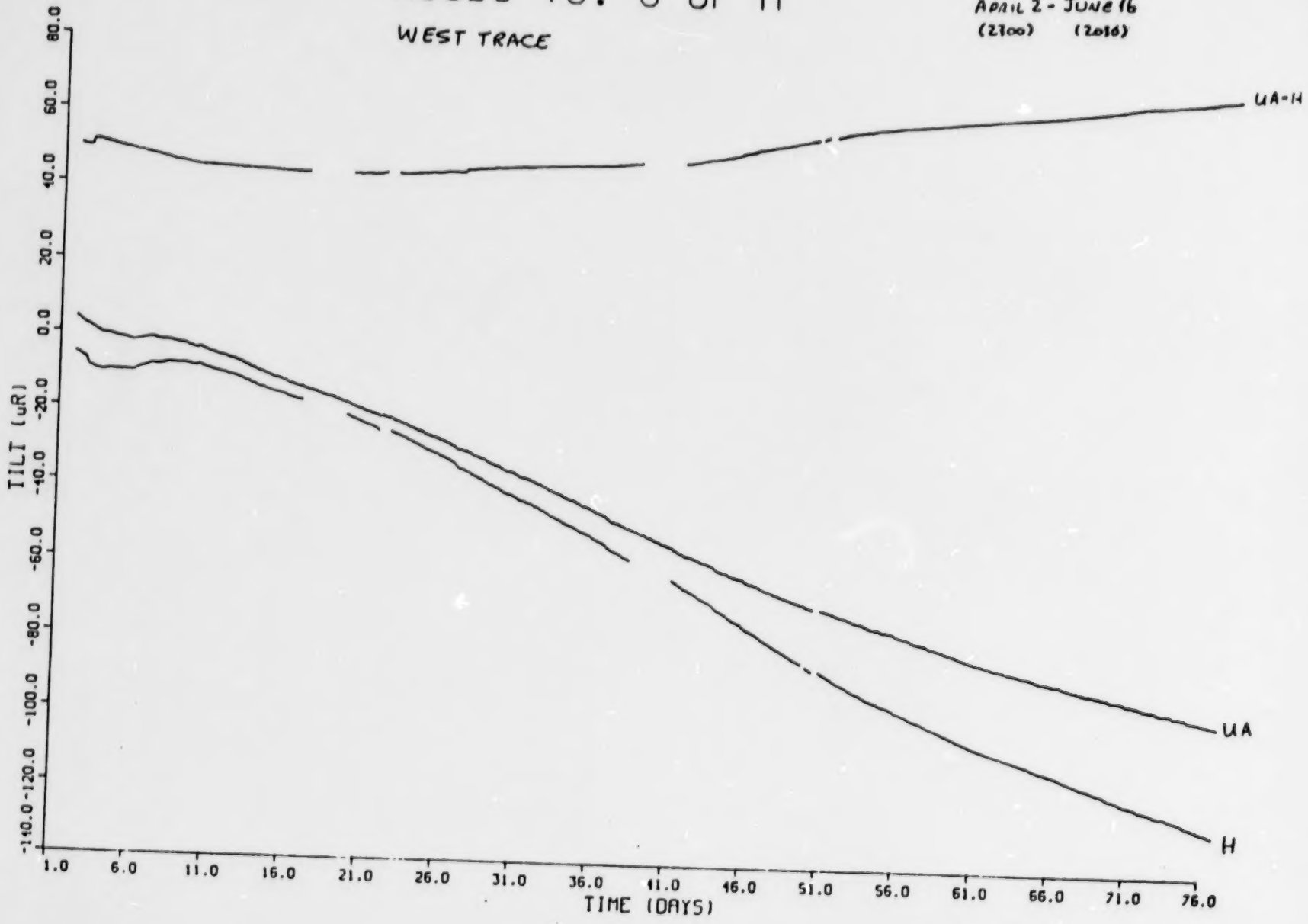

Fig. 4

Figure 5

Comparison of the change in injection rate from one day to the next (Δ Hall) with the change in tilt from one day to the next (Δ Tilt) for the **x-component of the North tiltmeter.**

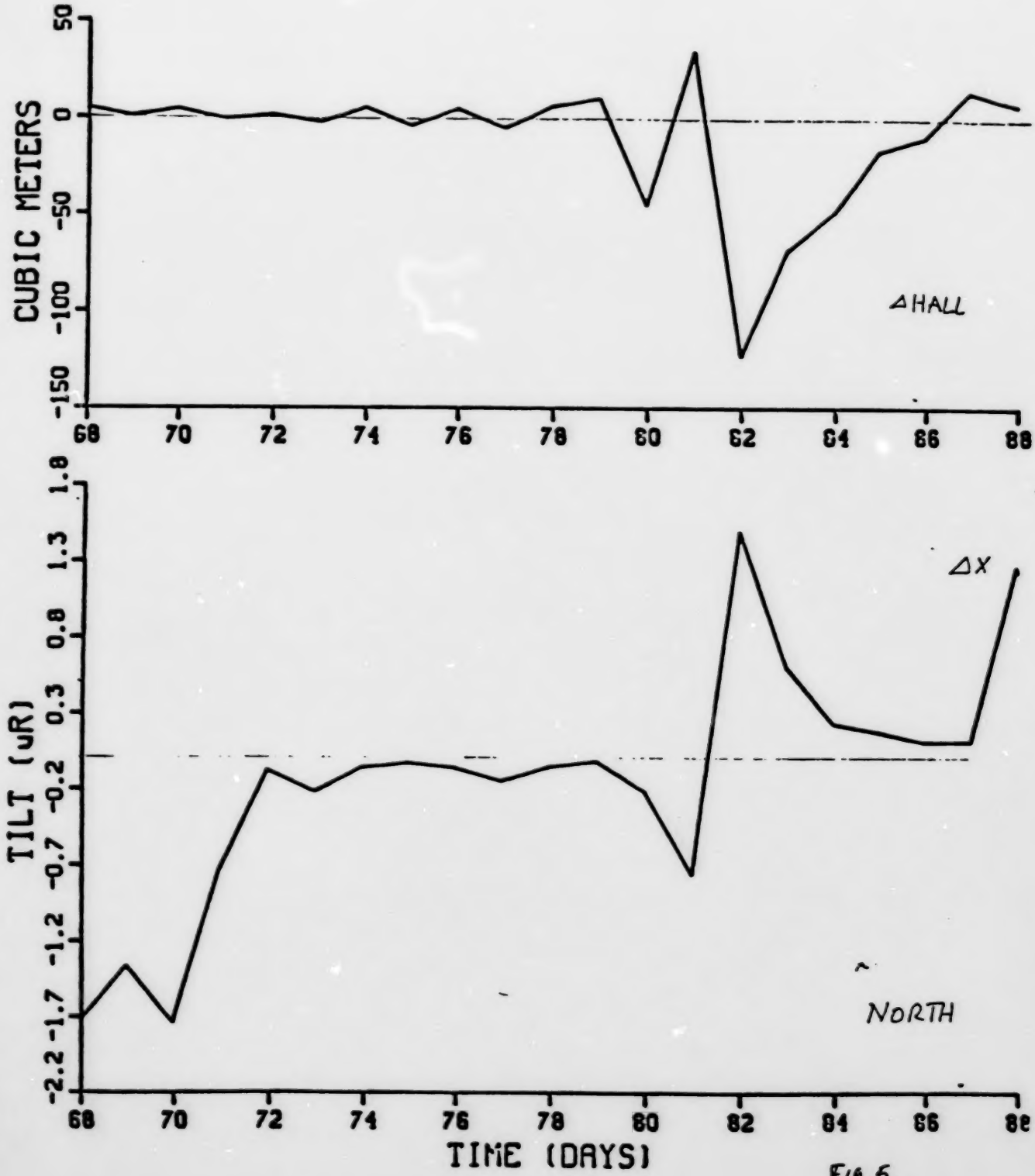
CUBIC METERS
50
0
-50
-100
-150
ΔHALL
68
70
72
74
76
78
80
82
84
86
88
TILT (uR)
1.8
1.3
0.8
0.3
-0.2
-0.7
-1.2
-1.7
-2.2
ΔX
NORTH
TIME (DAYS)

Fig. 5

Figure 6

Tilt trajectories

GLISP

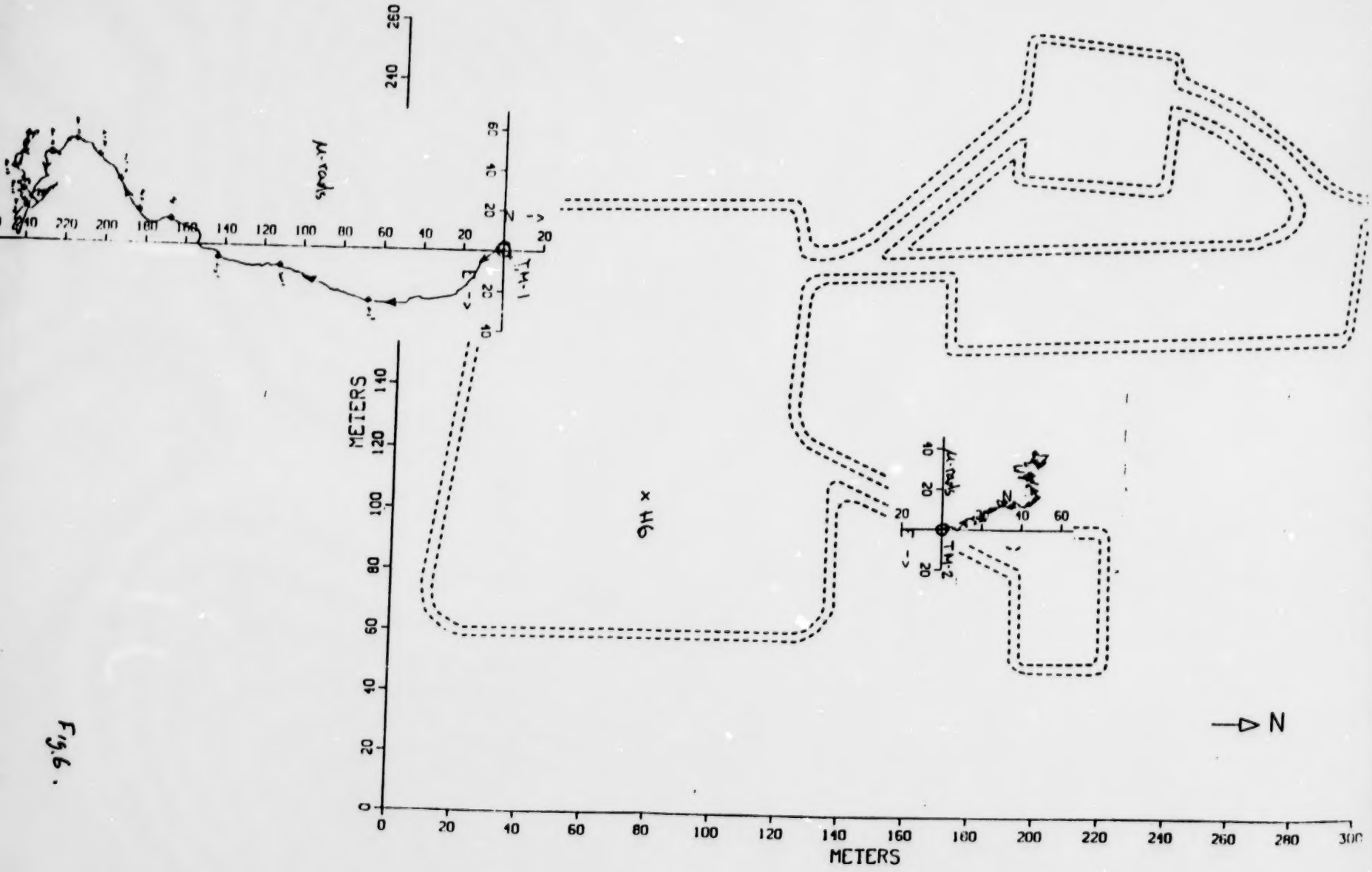
METERS
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
METERS
N
TM-1
TM-2
N16

Fig. 6.